CP violation in polarized $B \to \pi\ell^+\ell^-$and $B \to \rho\ell^+\ell^-$decays

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Abstract

We study the decay rate and the CP violating asymmetry of the exclusive $B \to \pi\ell^+\ell^-$and $B \to \rho\ell^+\ell^-$ decays in the case where one of the final leptons is polarized. We calculate the contributions coming from the individual polarization states in order to identify a so-called wrong sign decay, which is a decay with a given polarization, whose width and CP asymmetry are smaller as compared to the unpolarized one. The results are presented for electron and tau leptons. We observe that in particular decay channels, one can identify a wrong sign decay which is more sensitive to new physics beyond the Standard Model.

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I. INTRODUCTION

The rare B decays, which are induced at quark level by flavour changing neutral currents (FCNC), have received a lot of attention, since they are very promising for investigating the Standard Model (SM) and searching for the new physics beyond it. Among these B-decays, the rare semileptonic ones have played a central role for a long time, since they offer the most direct methods to determine the weak mixing angles and Cabibbo-Kobayashi-Maskawa (CKM) matrix elements. These decays can also be very useful to test the various new physics scenarios like the two Higgs doublet models (2HDM), minimal supersymmetric standard model (MSSM) [1]etc.

From experimental side, there is an impressive effort to search for B-decays, in B-factories such as Belle, BaBar, LHC-B. CLEO Collaboration reports for the branching ratios (BR) of the $B^0 \to \pi^- \ell^+ \nu$ and $B^0 \to \rho^- \ell^+ \nu$ decays [2] as

$$\begin{aligned} BR(B^0 \to \pi^- \ell^+ \nu) &= (1.8 \pm 0.4 \pm 0.3 \pm 0.2) \times 10^{-4}\,, \\ BR(B^0 \to \rho^- \ell^+ \nu) &= (2.57 \pm 0.29^{+0.33}_{-0.46} \pm 0.41) \times 10^{-4}. \end{aligned} \tag{1}$$

From these results, the value of the CKM matrix element $|V_{ub}| = 3.25 \pm 0.14^{+0.21}_{-0.29} \pm 0.55$ has been determined [2]. Recently, the BR of the inclusive $B \to X_s \ell^+ \ell^-$ decay has been also reported by Belle Collaboration [3];

$$BR(B \to X_s \ell^+ \ell^-) = (6.1 \pm 1.4^{+1.4}_{-1.1}) \times 10^{-6}\,, \tag{2}$$

which is very close to the value predicted by the SM [4]. The experimental result from BaBar collaboration for this BR is [5]:

$$BR(B \to X_s \ell^+ \ell^-) = (6.3 \pm 1.6^{+1.8}_{-1.5}) \times 10^{-6}\,. \tag{3}$$

From theoretical point of view exclusive channels are harder to evaluate than inclusive channels, because exclusive channels require an additional knowledge about form factors, which are used to incorporate hadronic effects. However, the exclusive channels are easier to measure. The decay channels that are induced by the $b \to d \ell^+ \ell^-$ decay at the quark level are promising for searching the CP violation. For the B decays that are induced by the decay $b \to s \ell^+ \ell^-$, the terms which describe virtual effects as $t\bar{t}$, $c\bar{c}$ and $u\bar{u}$ loops are in the matrix element proportional to $V_{tb}V^*_{ts}$, $V_{ub}V^*_{us}$ and $V_{cb}V^*_{cs}$ respectively. Because of the unitary

property of the CKM matrix and because of the fact that $V_{ub}V_{us}^*$ is small compared to the other CKM factors, the CP violation is strongly suppressed in these decays [6, 7]. Although the BR of the B decays induced by $b \to d\ell^+\ell^-$ are smaller, the CKM factors $V_{tb}V_{td}^*$, $V_{ub}V_{ud}^*$ and $V_{cb}V_{cd}^*$ are all of the same order. Therefore CP violation is much more considerable in these decays [8]. In this context, the exclusive $B_d \to (\pi, \rho, \eta, \eta')\,\ell^+\ell^-$, and $B_d \to \gamma\,\ell^+\ell^-$ decays have been extensively studied in the SM [9]-[11] and beyond [12]-[16].

In [17], it has been observed that the unpolarized CP asymmetry and decay width for the inclusive $b \to d\ell^+\ell^-$ decay are comparable to the CP asymmetry and decay width when one of the leptons is in a specific polarization state. The CP asymmetry as well as the decay rate in the case of the other polarization state turn out to be smaller as compared to the unpolarized spectrum and in [17] this is defined as the *wrong sign* polarized state. Along this line, in [18], a similar analysis about the CP asymmetries in $b \to d\ell^+\ell^-$ decays has been performed in a model independent way and it was reported that polarized asymmetries are very sensitive to various new Wilson coefficients. In this paper, motivated by the works in [17, 18], we make a similar analysis to the exclusive $B \to \pi\ell^+\ell^-$and $B \to \rho\ell^+\ell^-$channels and calculate the contributions coming from the individual polarization states in order to identify a wrong sign decay. This feature can provide measurements involving a new physics search.

Our paper is organized as follows. In section II we present the effective Hamiltonian and derive the expressions for the unpolarized and the polarized differential decay rates of $B \to \pi\ell^+\ell^-$and $B \to \rho\ell^+\ell^-$. The CP violating asymmetries for these decays in the unpolarized as well as in the polarized case are calculated in section III. The numerical results and the discussions are presented in section IV which is followed by a conclusion section.

II. EXCLUSIVE $B \to \pi \ell^+ \ell^-$ AND $B \to \rho \ell^+ \ell^-$ DECAYS

A. Effective Hamiltonian

The leading order QCD corrected effective Hamiltonian, which is induced by the corresponding quark level process $b \to d\, \ell^+ \ell^-$, is given by [19]-[22]:

$$\mathcal{H}_{eff} = \frac{4 G_F\, \alpha}{\sqrt{2}} V_{tb} V_{td}^* \Bigg\{ \sum_{i=1}^{10} \;\; C_i(\mu)\, O_i(\mu) - \lambda_u \{ C_1(\mu) [O_1^u(\mu) - O_1(\mu)] \\ + C_2(\mu) [O_2^u(\mu) - O_2(\mu)] \} \Bigg\}, \tag{4}$$

where

$$\lambda_u = \frac{V_{ub} V_{ud}^*}{V_{tb} V_{td}^*}, \tag{5}$$

using the unitarity of the CKM matrix i.e., $V_{tb}V_{td}^* + V_{ub}V_{ud}^* = -V_{cb}V_{cd}^*$. The explicit forms of the operators O_i can be found in refs. [19, 22]. In Eq.(4), $C_i(\mu)$ are the Wilson coefficients calculated at a renormalization point μ and their evolution from the higher scale $\mu = m_W$ down to the low-energy scale $\mu = m_b$ is described by the renormalization group equation. For C_7^{eff} this calculation is performed upto next-to-next-to-leading logarithmic (NNLL) order in refs.[23]-[25], while C_9^{eff} and C_{10} were calculated in [26]. In the context of the SM NNLL QCD corrections to the BR [26]-[30] and the forward-backward asymmetry [31]- [34] in $B \to X_s \ell^+ \ell^-$ are also available. For a recent review see e.g. [35]. The corresponding NNLL results for $B \to X_d \ell^+ \ell^-$ are given in [36].

The term that is the source of the CP violation can be parameterized as follows:

$$C_9^{eff} = \xi_1 + \lambda_u \xi_2, \tag{6}$$

where

$$\begin{aligned} \xi_1 \;=\; & C_9 + g(\hat{m}_c, s)(3C_1 + C_2 + 3C_3 + C_4 + 3C_5 + C_6) \\ & - \frac{1}{2} g(\hat{m}_d, s)(C_3 + C_4) - \frac{1}{2} g(\hat{m}_b, s)(4C_3 + 4C_4 + 3C_5 + C_6) \\ & + \frac{2}{9}(3C_3 + C_4 + 3C_5 + C_6), \end{aligned} \tag{7}$$

and

$$\xi_2 = [g(\hat{m}_c, s) - g(\hat{m}_u, s)](3C_1 + C_2). \tag{8}$$

In Eqs.(7) and (8), $s = q^2/m_B^2$ where q is the momentum transfer and $\hat{m}_q = m_q/m_b$. The functions $g(\hat{m}_q, s)$ arise from one loop contributions of the four-quark operators $O_1 - O_6$ and are given by

$$
\begin{aligned}
g(\hat{m}_q, s) &= -\frac{8}{9}\ln \hat{m}_q + \frac{8}{27} + \frac{4}{9}y \\
&\quad -\frac{2}{9}(2+y)|1-y|^{1/2} \begin{cases} \left(\ln\left|\frac{\sqrt{1-y}+1}{\sqrt{1-y}-1}\right| - i\pi\right), & \text{for } y \equiv \frac{4\hat{m}_q^2}{s} < 1 \\ 2\arctan\frac{1}{\sqrt{y-1}}, & \text{for } y \equiv \frac{4\hat{m}_q^2}{s} > 1\,. \end{cases}
\end{aligned}
\tag{9}
$$

C_9^{eff} term receives also contributions from long-distance effects. The $c\bar{c}$ resonance can be parameterized by means of a Breit-Wigner shape [37]. It is incorporated in the C_9^{eff} term by the following replacement,

$$
g(\hat{m}_c, s) \to g(\hat{m}_c, s) - \frac{3\pi}{\alpha^2}\kappa \sum_{V=J/\psi,\psi',\ldots} \frac{m_V Br(V \to \ell^+\ell^-)\Gamma^V_{total}}{s m_B^2 - m_V^2 + i m_V \Gamma^V_{total}}. \tag{10}
$$

To reproduce the correct experimental BR for $Br(B \to J/\psi X \to X\ell\bar{\ell}) = Br(B \to J/\psi X)Br(J/\psi \to X\ell\bar{\ell})$, the factor κ is taken to be 2.3 [37].

Neglecting the mass of the d quark, the effective short distance Hamiltonian for the $b \to d\ell^+\ell^-$ decay in Eq.(4) leads to the QCD corrected matrix element:

$$
\begin{aligned}
\mathcal{M} &= \frac{G_F \alpha}{2\sqrt{2}\pi} V_{tb}V_{td}^* \Bigg\{ C_9^{eff}(m_b)\ \bar{d}\gamma_\mu(1-\gamma_5)b\,\bar{\ell}\gamma^\mu\ell + C_{10}(m_b)\ \bar{d}\gamma_\mu(1-\gamma_5)b\,\bar{\ell}\gamma^\mu\gamma_5\ell \\
&- \ 2C_7^{eff}(m_b)\ \frac{m_b}{q^2}\bar{d}i\sigma_{\mu\nu}q^\nu(1+\gamma_5)b\,\bar{\ell}\gamma^\mu\ell \Bigg\}.
\end{aligned}
\tag{11}
$$

B. The exclusive $B \to \pi\ell^+\ell^-$ decay

In this section we present the expressions for the differential decay rate of $B \to \pi\ell^+\ell^-$decay with both unpolarized and polarized leptons. For this purpose, we need the following matrix elements, which are written in terms of the form factors:

$$
\langle\pi(p_\pi)|\bar{d}\gamma_\mu(1-\gamma^5)b|B(p_B)\rangle = f^+(q^2)(p_B+p_\pi)_\mu + f^-(q^2)q_\mu, \tag{12}
$$

$$
\langle\pi(p_\pi)|\bar{d}i\sigma_{\mu\nu}q^\nu(1+\gamma^5)b|B(p_B)\rangle = [q^2(p_B+p_\pi)_\mu - q_\mu(m_B^2-m_\pi^2)]f_v(q^2). \tag{13}
$$

Here, p_π and p_B are the four momenta of the π and the B meson, respectively. Also f^+, f^- and $f_v = -\frac{f_T}{m_B+m_\pi}$ represent the relevant form factors.

From Eq. (11), and using the matrix elements in Eqs. (12) and (13), we obtain the amplitude governing the $B \to \pi \ell^+ \ell^-$decay:

$$\mathcal{M}^{\mathcal{B}\to\pi} = \frac{G_F \alpha}{2\sqrt{2}\pi} V_{tb} V_{td}^* \Bigg\{ (2A p_\pi^\mu + B q^\mu) \bar{\ell}\gamma_\mu \ell + (2G p_\pi^\mu + D q^\mu) \bar{\ell}\gamma_\mu \gamma^5 \ell \Bigg\}, \tag{14}$$

where

$$\begin{aligned} A &= C_9^{eff} f^+ - 2 m_B C_7^{eff} f_v, \\ B &= C_9^{eff}(f^+ + f^-) + 2\frac{m_B}{q^2} C_7^{eff} f_v (m_B^2 - m_\pi^2 - q^2), \\ G &= C_{10} f^+, \\ D &= C_{10}(f^+ + f^-). \end{aligned} \tag{15}$$

Using the matrix element in Eq. (14), performing summation over final lepton polarizations and integrating over angle variables, the unpolarized differential decay width is obtained as,

$$\left(\frac{d\Gamma^\pi}{ds}\right)_0 = \frac{G_F^2 \alpha^2}{2^{10}\pi^5} |V_{tb} V_{td}{}^*|^2 m_B^3 \; v \; \sqrt{\lambda_\pi} \; \Delta_\pi, \tag{16}$$

where

$$\begin{aligned} \Delta_\pi = & \; \frac{1}{3} \, m_B^2 \; \lambda_\pi (3 - v^2)(|A|^2 + |G|^2) + 16 \; m_\ell^2 \; r_\pi \; |G|^2 + 4 \; m_\ell^2 \; s \; |D|^2 \\ & + 8 \; m_\ell^2 \; (1 - r_\pi - s) \mathrm{Re}[G D^*], \end{aligned} \tag{17}$$

with $r_\pi = m_\pi^2/m_B^2$, $\lambda_\pi = r_\pi^2 + (s-1)^2 - 2r_\pi(s+1)$, $v = \sqrt{1 - \frac{4t^2}{s}}$ and $t = m_\ell/m_B$.

In order to calculate the polarized decay spectrum, we need the final lepton polarizations. For this, one defines orthogonal unit vectors $\vec{e}_L$, $\vec{e}_T$ and $\vec{e}_N$ such that in the rest frame of ℓ^- lepton they are written as,

$$\begin{aligned} S_L^\mu &\equiv (0, \vec{e}_L) = \left(0, \frac{\vec{p}_1}{|\vec{p}_1|}\right), \\ S_N^\mu &\equiv (0, \vec{e}_N) = \left(0, \frac{\vec{k} \times \vec{p}_1}{|\vec{k} \times \vec{p}_1|}\right), \\ S_T^\mu &\equiv (0, \vec{e}_T) = \left(0, \vec{e}_N^{\,-} \times \vec{e}_L^{\,-}\right). \end{aligned} \tag{18}$$

Here, $\vec{p}_1$ is the 3-vector of ℓ^- lepton and $\vec{k}$ is the 3-vector of the final meson. The longitudinal unit vector S_L is boosted to the CM frame of $\ell^+\ell^-$ by Lorentz transformation:

$$S_{L,CM}^\mu = \left(\frac{|\vec{p}_1|}{m_\ell}, \frac{E_\ell \; \vec{p}_1}{m_\ell |\vec{p}_1|}\right), \tag{19}$$

while S_T and S_N are not changed by the boost. The differential decay rate of the $B \to \pi\ell^+\ell^-$decay, for any spin direction $\vec{n}$ of ℓ^- can be written in the following form

$$\frac{d\Gamma^\pi(s,\vec{n})}{ds} = \frac{1}{2}\left(\frac{d\Gamma^\pi}{ds}\right)_0 \left[1 + P_i^\pi \vec{e}_i \cdot \vec{n}\right] \;, \tag{20}$$

where a sum over $i = L, T, N$ is implied. Polarization components P_i^π in Eq. (20) are defined as

$$P_i^\pi(s) = \frac{d\Gamma^\pi(\vec{n}=\vec{e}_i)/ds - d\Gamma^\pi(\vec{n}=-\vec{e}_i)/ds}{d\Gamma^\pi(\vec{n}=\vec{e}_i)/ds + d\Gamma^\pi(\vec{n}=-\vec{e}_i)/ds}\,. \tag{21}$$

The resulting expressions for the polarization asymmetries are obtained as

$$\begin{aligned} P_L^\pi &= \frac{4m_B^2}{3\Delta_\pi}\, v\, \lambda_\pi\, \mathrm{Re}[AG^*]\,, \\ P_T^\pi &= \frac{m_B^2}{\sqrt{s}\Delta_\pi}\, \sqrt{\lambda_\pi}\, \pi\, t\, \Big(\mathrm{Re}[AD^*]s + \mathrm{Re}[AG^*](1 - r_\pi - s)\Big)\,, \\ P_N^\pi &= 0\,. \end{aligned} \tag{22}$$

Our results for P_L^π and P_T^π agree with the ones given in ref. [38]. As can be seen from the explicit expressions of P_i^π, the polarization P_T^π is proportional to m_ℓ and therefore can be significant for τ lepton only.

C. The exclusive $B \to \rho\ell^+\ell^-$decay

In this section we present the expressions for the differential decay rate for $B \to \rho\ell^+\ell^-$decay with both unpolarized and polarized leptons. For this, we need the following matrix elements:

$$\begin{aligned} <\rho(p_\rho,\varepsilon)|\bar{d}\gamma_\mu(1-\gamma_5)b|B(p_B)> &= -\epsilon_{\mu\nu\lambda\sigma}\varepsilon^{*\nu}p_\rho^\lambda p_B^\sigma \frac{2V(q^2)}{m_B+m_\rho} - i\varepsilon_\mu^*(m_B+m_\rho)A_1(q^2) \\ &+ i(p_B+p_\rho)_\mu(\varepsilon^* q)\frac{A_2(q^2)}{m_B+m_\rho} + iq_\mu(\varepsilon^* q)\frac{2m_\rho}{q^2}[A_3(q^2) \\ &-A_0(q^2)], \end{aligned} \tag{23}$$

$$\begin{aligned} <\rho(p_\rho,\varepsilon)|\bar{d}i\sigma_{\mu\nu}q^\nu(1+\gamma_5)b|B(p_B)> &= 4\epsilon_{\mu\nu\lambda\sigma}\varepsilon^{*\nu}p_\rho^\lambda q^\sigma T_1(q^2) + 2i[\varepsilon_\mu^*(m_B^2-m_\rho^2) \\ &- (p_B+p_\rho)_\mu(\varepsilon^* q)]T_2(q^2) + 2i(\varepsilon^* q) \\ &\left(q_\mu - (p_B+p_\rho)_\mu\frac{q^2}{m_B^2-m_\rho^2}\right)T_3(q^2), \end{aligned} \tag{24}$$

$$< \rho(p_\rho, \varepsilon)|\bar{d}(1+\gamma_5)b|B(p_B) >= \frac{-1}{m_b} 2im_\rho(\varepsilon^* q)A_0(q^2)\,, \tag{25}$$

where p_ρ and ε denote the four momentum and polarization vectors of the ρ meson, respectively.

From Eqs. (23-25), we get the following expression for the matrix element of the $B \to \rho \ell^+ \ell^-$decay:

$$\begin{aligned}
\mathcal{M}^{\mathcal{B}\to\rho} &= \frac{G_F \alpha}{2\sqrt{2}\pi} V_{tb} V_{td}^* \\
&\Big\{ \bar{\ell}\gamma_\mu(1-\gamma_5)\ell[2A\epsilon_{\mu\nu\lambda\sigma}\varepsilon^{*\nu} p_\rho^\lambda p_B^\sigma + iB\varepsilon_\mu^* - iC(p_B+p_\rho)_\mu(\varepsilon^* q) - iD(\varepsilon^* q)q_\mu] \\
&+ \bar{\ell}\gamma_\mu(1+\gamma_5)\ell[2E\epsilon_{\mu\nu\lambda\sigma}\varepsilon^{*\nu} p_\rho^\lambda p_B^\sigma + iF\varepsilon_\mu^* - iG(\varepsilon^* q)(p_B+p_\rho) - iH(\varepsilon^* q)q_\mu] \Big\}
\end{aligned} \tag{26}$$

where

$$\begin{aligned}
A &= (C_9^{eff} - C_{10})\frac{V}{m_B + m_\rho} + 4\frac{m_b}{q^2} C_7^{eff} T_1, \\
B &= (m_B + m_\rho)\left((C_9^{eff} - C_{10})A_1 + \frac{4m_b}{q^2}(m_B^2 - m_\rho^2) C_7^{eff} T_2\right), \\
C &= (C_9^{eff} - C_{10})\frac{A_2}{m_B + m_\rho} + 4\frac{m_b}{q^2} C_7^{eff}\left(T_2 + \frac{q^2}{m_B^2 - m_\rho^2} T_3\right), \\
D &= 2(C_9^{eff} - C_{10})\frac{m_\rho}{q^2}(A_3 - A_0) - 4C_7^{eff}\frac{m_b}{q^2} T_3, \\
E &= A(C_{10} \to -C_{10}), \\
F &= B(C_{10} \to -C_{10}), \\
G &= C(C_{10} \to -C_{10}), \\
H &= D(C_{10} \to -C_{10}).
\end{aligned} \tag{27}$$

Here A_0, A_1, A_2, A_3, V, T_1, T_2 and T_3 are the relevant form factors.

Using the matrix element in Eq. (26), we find the unpolarized differential decay width as,

$$\left(\frac{d\Gamma^\rho}{ds}\right)_0 = \frac{\alpha^2 G_F^2 m_B}{2^{12}\pi^5} |V_{tb} V_{td}^*|^2 \; v \; \sqrt{\lambda_\rho}\; \Delta_\rho\,, \tag{28}$$

where

$$
\begin{aligned}
\Delta_\rho \;=\;& \frac{8}{3} m_B^4 \lambda_\rho \Big[(m_B^2 s - m_\ell^2) \left(|A|^2 + |E|^2 \right) + 6 m_\ell^2 \,\mathrm{Re}(AE^*) \Big] \\
+\;& 24 m_\ell^2 \,\mathrm{Re}(BF^*) + \frac{1}{r_\rho} m_B^4 m_\ell^2 s \lambda_\rho \; |D-H|^2 \\
+\;& \frac{2}{r_\rho} m_B^2 m_\ell^2 \lambda_\rho \Big(\mathrm{Re}[B(-D^* + G^* + H^*)] + \mathrm{Re}[F(C^* + D^* - H^*)] \Big) \\
+\;& \frac{1}{2} m_\ell \,\mathrm{Re}[(C-G)(D^* - H^*)] - \frac{2}{r_\rho} m_B^4 m_\ell^2 \lambda_\rho (2 + 2r_\rho - s)\,\mathrm{Re}(CG^*) \Big) \\
-\;& \frac{2}{3 r_\rho s} m_B^2 \lambda_\rho \Big[m_\ell^2 (2 - 2r_\rho + s) + m_B^2 s (1 - r_\rho - s) \Big] \Big[\mathrm{Re}(BC^*) + \mathrm{Re}(FG^*) \Big] \\
+\;& \frac{1}{3 r_\rho s} \Big[2 m_\ell^2 (\lambda_\rho - 6 r_\rho s) + m_B^2 s (\lambda_\rho + 12 r_\rho s) \Big] \left(|B|^2 + |F|^2 \right) \\
+\;& \frac{1}{3 r_\rho s} m_B^4 \lambda_\rho \Big(m_B^2 s \lambda_\rho + m_\ell^2 [2\lambda_\rho + 3s(2 + 2r_\rho - s)] \Big) \left(|C|^2 + |G|^2 \right) , \qquad (29)
\end{aligned}
$$

where $\lambda_\rho = r_\rho^2 + (s-1)^2 - 2r_\rho(s+1)$ and $r_\rho = m_\rho^2/m_B^2$.

The polarization components are obtained in the same way as in the previous section. The differential decay rate of the $B \to \rho \ell^+ \ell^-$decay, for any spin direction $\vec{n}$ of ℓ^- can be written in the following form:

$$
\frac{d\Gamma^\rho(s,\vec{n})}{ds} = \frac{1}{2} \left(\frac{d\Gamma^\rho}{ds} \right)_0 [1 + P_i^\rho \vec{e}_i \cdot \vec{n}] \ , \qquad (30)
$$

where a sum over $i = L, T, N$ is implied. The resulting expressions for the polarization asymmetries are obtained as,

$$
\begin{aligned}
P_L^\rho \;=\;& \frac{-1}{3 r_\rho \Delta_\rho} m_B^2 v \Big(8 m_B^4 s r_\rho \lambda_\rho (|E|^2 - |A|^2) - (12 r_\rho s + \lambda_\rho)(|B|^2 - |F|^2) + m_B^4 \lambda_\rho^2 (|G|^2 - |C|^2) \\
-\;& 2 m_B^2 \lambda_\rho (-1 + r_\rho + s) \mathrm{Re}[CB^* - FG^*] \Big) \ , \\
P_T^\rho \;=\;& \frac{-1}{4 r_\rho \sqrt{s} \Delta_\rho} m_B m_\ell \pi \sqrt{\lambda_\rho} \Big(m_B^4 \lambda_\rho (r_\rho - 1)(|C|^2 - |G|^2) + m_B^2 s (1 + 3r_\rho - s) \mathrm{Re}[CF^* - BG^*] \\
&+ 8 r_\rho s m_B^2 \mathrm{Re}[(A+E)(B^* + F^*)] + m_B^2 (\lambda_\rho + (-1 + r_\rho + s)(r_\rho - 1)) \mathrm{Re}[BC^* - FG^*] \\
+\;& (-1 + r_\rho + s)(|B|^2 - |F|^2 + s m_B^2 \mathrm{Re}[(B+F)(H^* - D^*)]) \\
+\;& m_B^4 s \lambda_\rho \mathrm{Re}[(C+G)(H^* - D^*)] \Big) \ , \qquad (31) \\
P_N^\rho \;=\;& \frac{1}{4 r_\rho \Delta_\rho} m_B^3 m_\ell \pi v \sqrt{s \lambda_\rho} \Big(8 \mathrm{Im}[EB^* + FA^*] - (1 - r_\rho - s) \mathrm{Im}[(B-F)(D^* - H^*)] \\
&- (1 + 3r_\rho - s) \mathrm{Im}[(B-F)(C^* - G^*)] + m_B^2 \lambda_\rho \mathrm{Im}[(C-G)(D^* - H^*)] \Big) .
\end{aligned}
$$

Our results for P_L^ρ, P_N^ρ and P_T^ρ agree with those given in [39] for the SM case. As can be seen from the explicit expressions of P_i^ρ, they involve various quadratic combinations of the

Wilson coefficients and hence they are quite sensitive to the new physics. The polarizations P_N^ρ and P_T^ρ are again proportional to m_ℓ as in the $B \to \pi \ell^+ \ell^-$decay and therefore can be significant for τ lepton only.

III. CP VIOLATION

A. CP Violating Asymmetry in $B \to \pi \ell^+ \ell^-$decay

In $B \to \pi \ell^+ \ell^-$decay with unpolarized final leptons, CP violating differential decay width asymmetry is defined as,

$$A_{CP}^\pi(s) = \frac{(d\Gamma^\pi/ds)_0 - (d\bar{\Gamma}^\pi/ds)_0}{(d\Gamma^\pi/ds)_0 - (d\bar{\Gamma}^\pi/ds)_0} = \frac{\Delta_\pi - \bar{\Delta}_\pi}{\Delta_\pi + \bar{\Delta}_\pi} \ , \tag{32}$$

where

$$\frac{d\Gamma^\pi}{ds} = \frac{d\Gamma(B \to \pi e^+ e^-)}{ds}, \ \frac{d\bar{\Gamma}^\pi}{ds} = \frac{d\Gamma(\bar{B} \to \bar{\pi} e^+ e^-)}{ds} \ .$$

In the SM, the Wilson coefficient C_9^{eff} is the only one that contributes to A_{CP} above since it has an imaginary component as well as a real one, which can be parameterized as in Eq.(6). Therefore, $(d\bar{\Gamma}^\pi/ds)_0$ and $\bar{\Delta}_\pi$ in Eq. (32) can be obtained from $(d\Gamma^\pi/ds)_0$ and Δ_π by making the replacement,

$$\left(\frac{d\bar{\Gamma}^\pi}{ds}\right)_0 = \left(\frac{d\Gamma^\pi}{ds}\right)_0 |_{\lambda_u \to \lambda_u^*} \quad , \quad \bar{\Delta}_\pi = \Delta_\pi \ |_{\lambda_u \to \lambda_u^*} \ . \tag{33}$$

Using Eqs. (17), (32) and (33), the CP violating asymmetry is obtained as

$$A_{CP}(s) \ = \ \frac{-2\mathrm{Im}[\lambda_u]\Sigma_\pi(s)}{\Delta_\pi + 2\mathrm{Im}[\lambda_u]\Sigma_\pi(s)} \ ,$$

where

$$\Sigma_\pi(s) = \frac{1}{3} m_B^2 \lambda_\pi (3 - v^2)(f^{+2} \mathrm{Im}[\xi_1^* \xi_2] - 2 m_B \ f_v f^+ \ \mathrm{Im}[\xi_2 \mathrm{C}_7^{\mathrm{eff}\,*}]). \tag{34}$$

When one of the leptons is polarized in $B \to \pi \ell^+ \ell^-$decay, CP violating asymmetry can be defined as follows:

$$A_{CP}^\pi(s, \vec{n}) = \frac{d\Gamma^\pi(s, \vec{n})/ds - d\bar{\Gamma}^\pi(s, \vec{\bar{n}} = -\vec{n})/ds}{(d\Gamma^\pi/ds)_0 + (d\bar{\Gamma}^\pi/ds)_0} \ , \tag{35}$$

where

$$\frac{d\Gamma^\pi(s, \vec{n})}{ds} = \frac{d\Gamma^\pi(B \to \pi e^+ e^-(\vec{n}))}{ds} \quad , \quad \frac{d\bar{\Gamma}^\pi(s, \vec{\bar{n}})}{ds} = \frac{B \to \pi e^+(\vec{\bar{n}}) e^-)}{ds} \ .$$

Here, $\vec{\bar{n}}$ is the spin direction of the ℓ^+ in the $\bar{B} \to \bar{\pi}\ell^+\ell^-$ decay. From the expression for the polarized differential decay width for the $B \to \pi\ell^+\ell^-$ decay given by Eq. (20), the width for the corresponding CP conjugated process reads,

$$\frac{d\bar{\Gamma}^\pi(s,\vec{\bar{n}})}{ds} = \frac{1}{2}\left(\frac{d\bar{\Gamma}^\pi}{ds}\right)_0 \left[1 + \bar{P}_i^\pi \vec{\bar{e}}_i \cdot \vec{\bar{n}}\right] \ . \tag{36}$$

Since in the CP conserving case $\bar{P}_i^\pi = -P_i^\pi$, in the general case with the choice $\vec{\bar{e}}_i = \vec{e}_i$, $\bar{P}_i^\pi$ can be constructed with the replacement,

$$\bar{P}_i^\pi = -P_i^\pi \mid_{\lambda_u \to \lambda_u^*} . \tag{37}$$

Inserting Eqs. (20) and (36) into Eq. (35), and setting $\vec{\bar{n}} = \vec{n}$, the CP violating asymmetry when lepton is polarized with $\vec{n} = \pm\vec{e}_i$ is given by,

$$A_{CP}^\pi(s,\vec{n} = \pm\vec{e}_i) \ = \ \frac{1}{2}\frac{(d\Gamma^\pi/ds)_0\left[1 \pm P_i^\pi\right] - (\bar{\Gamma}^\pi/ds)_0\left[1 \pm \bar{P}_i^\pi\right]}{(d\Gamma^\pi/ds)_0 + (d\bar{\Gamma}^\pi/ds)_0} ,$$

or, by making use of the replacements in Eq. (33) and Eq. (37) we further obtain,

$$\begin{aligned}
A_{CP}^\pi(s,\vec{n} = \pm\vec{e}_i) \ &= \ \frac{1}{2}\left\{\frac{(d\Gamma^\pi/ds)_0 - (d\bar{\Gamma}^\pi/ds)_0}{(d\Gamma^\pi/ds)_0 - (d\bar{\Gamma}^\pi/ds)_0} \pm \frac{(d\Gamma^\pi/ds)_0 P_i^\pi - ((d\Gamma^\pi/ds)_0 P_i^\pi) \mid_{\lambda_u \to \lambda_u^*}}{(d\Gamma^\pi/ds)_0 - (d\bar{\Gamma}^\pi/ds)_0}\right\} \\
&= \ \frac{1}{2}\left\{A_{CP}^\pi(s) \pm \delta {A_{CP}^\pi}^i(s)\right\} \ .
\end{aligned} \tag{38}$$

The $\delta A_{CP}^i(s)$ terms in Eq. (38) describe the modifications to the unpolarized decay width, which can be written as,

$$\delta {A_{CP}^\pi}^i(s) \ = \ \frac{-2\mathrm{Im}[\lambda_u]\delta\Sigma_\pi^i(s)}{\Delta_\pi(s) + 2\mathrm{Im}[\lambda_u]\Sigma_\pi(s)} , \tag{39}$$

where

$$\delta\Sigma_\pi^L(s) \ = \ \frac{2}{3}\, m_B^2 \ v \ \lambda_\pi \ {f^+}^2 \mathrm{Im}[\xi_2 C_{10}^*] , \tag{40}$$

$$\delta\Sigma_\pi^T(s) \ = \ \frac{m_B^2 \ t \ \pi \ \sqrt{\lambda_\pi}}{2\sqrt{s}} \ ((1 - r_\pi){f^+}^2 + s f^+ f^-)\mathrm{Im}[\xi_2 C_{10}^*] , \tag{41}$$

$$\delta\Sigma_\pi^N(s) \ = \ 0 . \tag{42}$$

B. CP Violating Asymmetry in $B \to \rho\ell^+\ell^-$decay

In $B \to \rho\ell^+\ell^-$ decay with unpolarized final leptons, CP violating differential decay width asymmetry is defined as in Eq.(32) with the replacement $\Delta_\pi \to \Delta_\rho$ and $d\Gamma^\pi/ds \to d\Gamma^\rho/ds$. Using Eqs. (29), (32) and (33), the CP violating asymmetry is given as,

$$A_{CP}^\rho(s) \ = \ \frac{-\mathrm{Im}[\lambda_u]\Sigma_\rho(s)}{2\Delta_\rho + \mathrm{Im}[\lambda_u]\Sigma_\rho(s)} ,$$

where

$$\Sigma_\rho(s) = \frac{4(s+2t)}{3r_\rho s(1+r_\rho)}\Bigg\{m_{B\rho}\mathrm{Im}[\xi_2]\Bigg[A_1 m_{B\rho}^2\Big(c_2 m_B^2(-1+r_\rho+s)\lambda_\rho + c_1(12r_\rho s+\lambda_\rho)\Big)$$
$$+ \; m_B^2\lambda_\rho\Big(8m_\rho^2 r_\rho s V c_3 + A_2(c_1(-1+r_\rho+s)+c_2 m_B^2\lambda_\rho)\Big)\Bigg]$$
$$-2\mathrm{Im}[\xi_1\xi_2^*]\Bigg[2A_1A_2 m_B^2 m_{B\rho}^2\lambda_\rho(-1+r_\rho+s) + A_1^2 m_{B\rho}^4(12r_\rho s+\lambda_\rho)$$
$$+ \; m_B^4\lambda_\rho(8r_\rho s V^2 + A_2^2\lambda_\rho)\Bigg]\Bigg\}, \qquad (43)$$

with $m_{B\rho} \equiv m_B + m_\rho$ and

$$c_1 = \frac{8m_b C_7^{eff}}{q^2}(m_B^2 - m_\rho^2)T_2 \;,\; c_2 = 8\frac{m_b}{q^2}C_7^{eff}\left(T_2 + \frac{q^2}{m_B^2-m_\rho^2}T_3\right),$$
$$c_3 = \frac{8m_b C_7^{eff}}{q^2}T_1 \;. \qquad (44)$$

When one of the leptons is polarized in $B \to \rho\ell^+\ell^-$ decay, CP violating asymmetry can be defined as follows:

$$A_{CP}^\rho(s,\vec{n}) = \frac{d\Gamma^\rho(s,\vec{n})/ds - d\bar{\Gamma}^\rho(s,\vec{\bar{n}}=-\vec{n})/ds}{(d\Gamma^\rho/ds)_0 + (d\bar{\Gamma}^\rho/ds)_0} \;, \qquad (45)$$

where

$$\frac{d\Gamma^\rho(s,\vec{n})}{ds} = \frac{d\Gamma(B\to\rho\ell^+\ell^-(\vec{n}))}{ds} \quad , \quad \frac{d\bar{\Gamma}^\rho(s,\vec{\bar{n}})}{ds} = \frac{B\to\rho\ell^+(\vec{\bar{n}})\ell^-)}{ds} \;.$$

Here, $\vec{\bar{n}}$ is the spin direction of the ℓ^+ in the $\bar{B}\to\bar{\rho}\ell^+\ell^-$ decay. From the expression for the polarized differential decay width in the $B\to\rho\ell^+\ell^-$ decay given by Eq. (30), the width for corresponding CP conjugated process reads

$$\frac{d\bar{\Gamma}^\rho(s,\vec{\bar{n}})}{ds} = \frac{1}{2}\left(\frac{d\bar{\Gamma}^\rho}{ds}\right)_0\left[1+\bar{P}_i^\rho\vec{\bar{e}}_i\cdot\vec{\bar{n}}\right] \;. \qquad (46)$$

Inserting Eqs. (30) and (46) into Eq. (45), and setting $\vec{\bar{n}}=\vec{n}$, the CP violating asymmetry when lepton is polarized with $\vec{n}=\pm\vec{e}_i$ is given by

$$A_{CP}^\rho(s,\vec{n}=\pm\vec{e}_i) = \frac{1}{2}\frac{(d\Gamma^\rho/ds)_0\left[1\pm P_i^\rho\right] - (\bar{\Gamma}^\rho/ds)_0\left[1\pm\bar{P}_i^\rho\right]}{(d\Gamma^\rho/ds)_0 + (d\bar{\Gamma}^\rho/ds)_0} \;,$$

or, by making use of the replacements in Eq. (33) and Eq. (37) with $\pi \to \rho$ we further obtain

$$
\begin{aligned}
A^{\rho}_{CP}(s,\vec{n}=\pm\vec{e}_i) &= \frac{1}{2}\left\{\frac{(d\Gamma^{\rho}/ds)_0-(d\bar{\Gamma}^{\rho}/ds)_0}{(d\Gamma^{\rho}/ds)_0-(d\bar{\Gamma}^{\rho}/ds)_0} \pm \frac{(d\Gamma^{\rho}/ds)_0 P^{\rho}_i - ((d\Gamma^{\rho}/ds)_0 P^{\rho}_i)\mid_{\lambda_u\to\lambda_u^*}}{(d\Gamma^{\rho}/ds)_0-(d\bar{\Gamma}^{\rho}/ds)_0}\right\} \\
&= \frac{1}{2}\left\{A^{\rho}_{CP}(s) \pm \delta A^{\rho\ i}_{CP}(s)\right\}\ . \qquad (47)
\end{aligned}
$$

The $\delta A^{\rho\ i}_{CP}(s)$ terms in Eq. (47) describe the modifications to the unpolarized decay width, which can be written as

$$
\delta A^{\rho\ i}_{CP}(s) = \frac{\mathrm{Im}\lambda_u\ \delta\Sigma^i_{\rho}(s)}{\Delta_{\rho}(s)+\bar{\Delta}_{\rho}(s)}\ , \qquad (48)
$$

where

$$
\begin{aligned}
\delta\Sigma^L_{\rho}(s) &= \frac{4m_B v}{3r_{\rho}(1+\sqrt{r_{\rho}})}\mathrm{Im}[\xi_2]\Bigg\{A_1 m^2_{B\rho}\Big(c'_2 m^2_B(-1+r+s)\lambda_{\rho}+c'_1(12r_{\rho}s+\lambda_{\rho})\Big) \\
&+\ m^2_B\lambda_{\rho}\Big(8m^2_{\rho}r_{\rho}sVc'_4+A_2(c'_1(-1+r_{\rho}+s)+c'_2m^2_B\lambda_{\rho})\Big)\Bigg\}, \qquad (49)
\end{aligned}
$$

$$
\begin{aligned}
\delta\Sigma^T_{\rho}(s) &= \frac{m^2_B m_{\ell}\pi}{r_{\rho}(1+\sqrt{r_{\rho}})}\frac{\sqrt{\lambda_{\rho}}}{\sqrt{s}}\Bigg\{-A_1 m^2_{B\rho}\mathrm{Im}[\xi_2]\Big[(-1+r_{\rho}+s)c'_1/m^2_B \\
&+\ (-1+r_{\rho}+s)(-1+r_{\rho})c'_2+s(8r_{\rho}c_3+(-1+r_{\rho}+s)c'_3)\Big] \\
&+\ \mathrm{Im}[\xi_2]\Big[8r_{\rho}sVc_1-A_2\lambda_{\rho}(c'_1+m^2_B((r_{\rho}-1)c'_2-sc'_3))\Big] \\
&-\ 32m_{B\rho}r_{\rho}sA_1V\mathrm{Im}[\xi_1\xi_2^*]\Bigg\}, \qquad (50)
\end{aligned}
$$

$$
\begin{aligned}
\delta\Sigma^N_{\rho}(s) &= \frac{m^2_B m_{\ell}\pi v}{2r_{\rho}(1+\sqrt{r_{\rho}})}\sqrt{\lambda_{\rho}}\sqrt{s}\mathrm{Re}[\xi_2]\Bigg\{(-A_2D_1+A_1D_2m^2_{B\rho})(-1-3r_{\rho}+s) \\
&-\ m_{B\rho}(-1+r_{\rho}+s)(A_1D_3m_{B\rho}-2D_1T_3/m_b)-8r_{\rho}(A_1c'_4m^2_{B\rho}+c'_1V)\Bigg\}, \qquad (51)
\end{aligned}
$$

where

$$
\begin{aligned}
c'_1 &= -2m_{B\rho}A_1C_{10}\quad,\quad c'_2=-2A_2C_{10}/m_{B\rho}\,, \\
c'_3 &= -4T_3C_{10}/m_b\quad,\quad c'_4=-2VC_{10}/m_{B\rho}\,, \qquad (52)
\end{aligned}
$$

and

$$D_1 \;=\; F(C_9^{eff} \to 0) \;,\; D_2 = G(C_9^{eff} \to 0) \;,\; D_3 = H(C_9^{eff} \to 0) \;. \tag{53}$$

IV. NUMERICAL RESULTS AND DISCUSSION

In this section we present the numerical analysis of both the exclusive decays $B \to \pi\ell^+\ell^-$and $B \to \rho\ell^+\ell^-$ for $\ell = e, \tau$. We do not present the results for $\ell = \mu$ because they are similar to the ones for $\ell = e$. The input parameters we used in our numerical analysis are as follows:

$$\begin{aligned}
&m_B = 5.28\, GeV \,,\, m_b = 4.8\, GeV \,,\, m_c = 1.4\, GeV \,,\, m_\tau = 1.78\, GeV \,,\, m_e = 0.511\, MeV,\\
&m_\mu = 0.106\, GeV,\, m_\pi = 0.14\, GeV \,,\, m_\rho = 0.77\, GeV \,,\, m_d = m_u = m_\pi = 0.14\, GeV \,,\\
&|V_{cb}| = 0.044 \,,\, \alpha^{-1} = 129 \,,\, G_f = 1.17 \times 10^{-5}\, GeV^{-2} \,,\, \tau_B = 1.56 \times 10^{-12}\, s \,.
\end{aligned} \tag{54}$$

Using the Wolfenstein parametrization of the CKM matrix [40], λ_u in Eq. (6) can be written as:

$$\lambda_u = \frac{\rho(1-\rho) - \eta^2 - i\eta}{(1-\rho)^2 + \eta^2} + O(\lambda^2). \tag{55}$$

Furthermore, we use the relation

$$\frac{|V_{tb}V_{td}^*|^2}{|V_{cb}|^2} \;=\; \lambda^2[(1-\rho)^2 + \eta^2] + \mathcal{O}(\lambda^4) \tag{56}$$

where $\lambda = \sin\theta_C \simeq 0.221$ and adopt the values of the Wolfenstein parameters as $\rho = 0.25$ and $\eta = 0.34$.

In order to obtain numerical results for the $B \to \pi\ell^+\ell^-$and $B \to \rho\ell^+\ell^-$decays, we also need the numerical values of the decay form factors. The literature on this subject is very rich; we give some of them here. For $B \to \pi(\rho)$ form factors are calculated in the constituent quark model [41] and using the light-cone QCD sum rules [42, 43]([44, 45]). In [46] the results of the lattice QCD calculations are given for the $B \to \pi, \rho$ form factors, while perturbative QCD approach [47] and the so-called large energy effective theory [48] have also been employed to calculate these form factors.

A. Numerical results of the exclusive $B \to \pi \ell^+ \ell^-$decay

In order to obtain numerical results for the $B \to \pi \ell^+ \ell^-$decay, we have made use of the results of the constituent quark model [41], where the form factors f_T and f_+ can be parameterized as:

$$f(q^2) = \frac{f(0)}{(1 - q^2/M^2)[1 - \sigma_1\ q^2/M^2 + \sigma_2\ q^4/M^4]}\,. \tag{57}$$

In this model, f_- is redefined as:

$$F_0 = f_+ + \frac{q^2}{(p_B + p_\pi)q} f_-\,, \tag{58}$$

and its interpolation formula is given as:

$$f(q^2) = \frac{f(0)}{[1 - \sigma_1\ q^2/M^2 + \sigma_2\ q^4/M^4]}\,. \tag{59}$$

The parameters $f(0)$, σ_1 and σ_2 can be found in Table I. Note that for f_+ and f_T a simple monopole two-parameter formula is used *viz.* $\sigma_2 = 0$.

	$f(0)$	σ_1	σ_2
f_+	0.29	0.48	
F_0	0.29	0.76	0.28
f_T	0.28	0.48	

TABLE I: $B \to \pi$ transition form factors in the constituent quark model.

In Fig.(1) we present our results of the differential branching ratios (dBR/ds) of the unpolarized and longitudinally polarized $B \to \pi e^+ e^-$decay. dBR/ds for $\vec{n} = -\vec{e}_L$ polarized case is close to the one of unpolarized decay, which implies that the decay is naturally left-handed. dBR/ds for the $\vec{n} = +\vec{e}_L$ polarization case is far below dBR/ds for the unpolarized one. Thus, $\vec{n} = +\vec{e}_L$ polarized $B \to \pi e^+ e^-$decay corresponds to a wrong sign decay.

In Figs.(2) and (3), we plot the longitudinally polarized asymmetries and the unpolarized CP violating asymmetry together with $-\delta A^L_{CP}$ of the $B \to \pi e^+ e^-$decay, respectively. From Fig.(2) it can be observed that $A_{CP}(\vec{n} = -\vec{e}_L)$ is much larger than $A_{CP}(\vec{n} = +\vec{e}_L)$. It is also observed from Fig.(3) that $-\delta A^L_{CP}$ exceeds the unpolarized A_{CP} in some kinematical regions but is mostly comparable with it. Particularly, in the region $(2m_\ell/m_B)^2 \le s \le$

$((m_{J/\psi}-0.02)/mB)^2$, which is free of resonance contribution, we find that δA^L_{CP} and A_{CP} are about 6%. We see also from Fig.(3) that in the resonance region δA^L_{CP} can reach values up to 25%.

In Fig.(4), we present dBR/ds for the decay $B \to \pi\tau^+\tau^-$ for unpolarized, longitudinally and transversely polarized τ leptons. We observe that dBR/ds for $\vec{n}=-\vec{e}_L$ and $\vec{n}=-\vec{e}_T$ are close to unpolarized dBR/ds, while it becomes smaller for $\vec{n}=+\vec{e}_L$ and $\vec{n}=+\vec{e}_T$. The $\vec{n}=+\vec{e}_T$ polarization case gives a very small dBR/ds as compared to the unpolarized decay thus can be identified as wrong sign decay.

In Fig.(5), we plot the unpolarized A_{CP} and longitudinally and transversely polarized $-\delta A_{CP}$ of the decay $B \to \pi\tau^+\tau^-$. We observe that although δA^L_{CP} is small, δA^T_{CP} is very close to A_{CP} especially in the resonance regions. Therefore, we can conclude that $A^L_{CP}(\vec{n}=+\vec{e}_i) \simeq A^L_{CP}(\vec{n}=-\vec{e}_i)$. The asymmetries reach to a maximum value of 13%.

B. Numerical results of the exclusive $B \to \rho\ell^+\ell^-$decay

In our numerical calculation for $B \to \rho\ell^+\ell^-$decay, we use three parameter fit of the light-cone QCD sum rule [44] which can be written in the following form:

$$F(q^2) = \frac{F(0)}{1-a_F\ q^2/m_B^2 + b_F(q^2/m_B^2)^2}\,, \tag{60}$$

where the values of the parameters $F(0)$, a_F and b_F are given in Table (II). The form factors A_0 and A_3 can be found from the following parametrization,

$$\begin{aligned} A_0 &= A_3 - \frac{T_3\ q^2}{m_\rho m_b}, \\ A_3 &= \frac{m_B+m_\rho}{2m_\rho}A_1 - \frac{m_B-m_\rho}{2m_\rho}A_2. \end{aligned} \tag{61}$$

In Fig.(6) we present dBR/ds for the decay $B \to \rho e^+e^-$ with unpolarized and longitudinally polarized electrons. It can be seen from this figure that the polarized spectrum for $\vec{n}=-\vec{e}_L$ almost coincides with unpolarized spectrum, whereas the polarized $\vec{n}=+\vec{e}_L$ spectrum is far below the unpolarized one. So, decay is naturally left handed in the SM.

In Figs.(7) and (8) we plot the longitudinally polarized CP violating asymmetries, $A_{CP}(\vec{n})$ with $\vec{n}=-\vec{e}_L$ and $\vec{n}=+\vec{e}_L$, and unpolarized A_{CP} together with the polarized quantity δA^L_{CP} for the decay $B \to \rho e^+e^-$, respectively. As can be seen from Fig.(7), $A_{CP}(\vec{n}=-\vec{e}_L)$ is much larger than $A_{CP}(\vec{n}=+\vec{e}_L)$. We see from Fig.(8) that polarized CP violating

	$F(0)$	a_F	b_F
$A_1^{B\to\rho}$	0.26 ± 0.04	0.29	-0.415
$A_2^{B\to\rho}$	0.22 ± 0.03	0.93	-0.092
$V^{B\to\rho}$	0.34 ± 0.05	1.37	0.315
$T_1^{B\to\rho}$	0.15 ± 0.02	1.41	0.361
$T_2^{B\to\rho}$	0.15 ± 0.02	0.28	-0.500
$T_3^{B\to\rho}$	0.10 ± 0.02	1.06	-0.076

TABLE II: $B \to \rho$ transition form factors in a three-parameter fit.

asymmetry δA_{CP}^L becomes larger than its unpolarized counterpart in some kinematic regions. Particularly, in the region $(2m_\ell/m_B)^2 \leq s \leq ((m_{J/\psi}-0.02)/mB)^2$, which is free of resonance contribution, we find that δA_{CP}^L is about 6%, while the unpolarized A_{CP} is about 4%. We see also from Fig.(8) that in the resonance region δA_{CP}^L can reach values up to 25%.

In Fig.(9), we present the dBR/ds for the decay $B \to \rho\tau^+\tau^-$ for unpolarized, longitudinally, transversely and normally polarized τ leptons. We see that dBR/ds for $\vec{n} = +\vec{e}_N$ and $\vec{n} = -\vec{e}_N$ almost coincide, while for $\vec{n} = \pm\vec{e}_L$, the state with $\vec{n} = -\vec{e}_L$ is much more comparable with the unpolarized dBR/ds with respect to the one with $\vec{n} = +\vec{e}_L$.

In Fig.(10), we give longitudinally, transversely and normally polarized and unpolarized CP violating rate asymmetries for the decay $B \to \rho\tau^+\tau^-$. We observe that δA_{CP}^T and δA_{CP}^N are both smaller than δA_{CP}^L. Therefore, we can conclude that $A_{CP}(\vec{n} = +\vec{e}_i) \simeq A_{CP}(\vec{n} = -\vec{e}_i)$ for $i = T, N$, while for $i = L$ $A_{CP}(\vec{n} = +\vec{e}_L)$ is quite small as compared to its counterpart with $\vec{n} = -\vec{e}_L$.

V. CONCLUSION

We have calculated the polarized decay rate and CP violating asymmetries of the decays $B \to \pi\ell^+\ell^-$and $B \to \rho\ell^+\ell^-$. For $\ell = e$ which is in specific polarized channel $\vec{n} = -\vec{e}_L$ the decay rate is comparable to the one of the unpolarized decay. The normal and the transverse polarizations are proportional to the mass of the lepton and therefore can be significant for τ lepton only. For the $B \to \pi\tau^+\tau^-$decay, $\vec{n} = \pm\vec{e}_L$ and for the $B \to \rho\tau^+\tau^-$decay $\vec{n} = \pm\vec{e}_T$ and $\vec{n} = \pm\vec{e}_N$ give similar widths. For the rest, which are defined as the wrong sign decays, the

decay rates and the CP violating asymmetries are much lower as compared to the unpolarized ones.

In conclusion, we studied the decay rate and the CP violating asymmetry of the exclusive $B \to \pi \ell^+ \ell^-$and $B \to \rho \ell^+ \ell^-$ decays in the case where one of the final leptons is polarized. Since the SM is naturally left-handed, the wrong sign decays, in particular $\vec{n} = +\vec{e}_L$ polarized $B \to (\pi, \rho) e^+ e^-$, $\vec{n} = +\vec{e}_T$ polarized $B \to \pi \tau^+ \tau^-$ and $\vec{n} = +\vec{e}_L$ polarized $B \to \rho \tau^+ \tau^-$ decays, are more sensitive to new physics. Taking into account the typical branching ratios and CP violating asymmetries, $10^{10} - 10^{11}$ $B\bar{B}$ pairs are needed for the observation of CP violation in the exclusive channels [9], which is a challenging task for the future hadron colliders. An unexpected large asymmetry in these channels and the wrong sign decays would be very significant in search for new physics beyond the SM.

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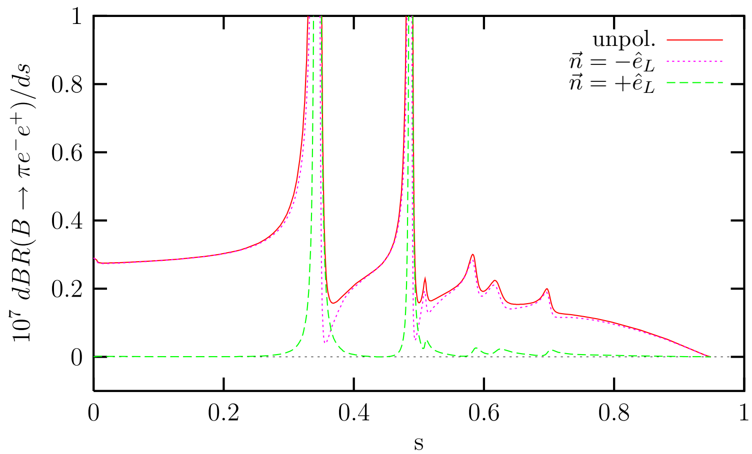

FIG. 1: Polarized and unpolarized differential branching ratios for $B \to \pi e^+ e^-$ decay.

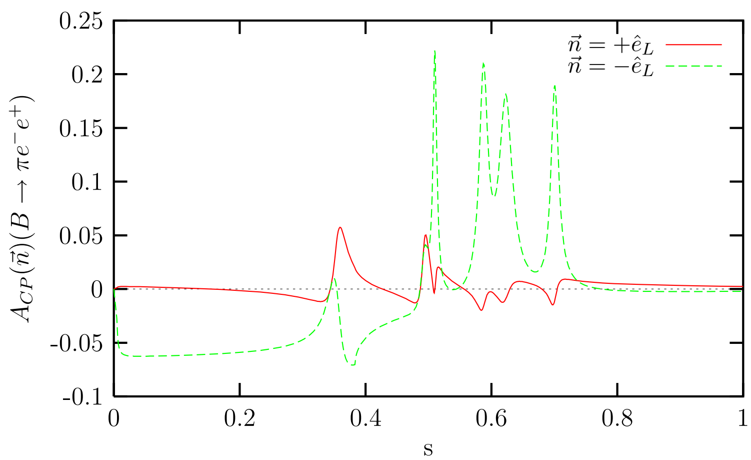

FIG. 2: Longitudinally polarized CP violating asymmetries for $B \to \pi e^+ e^-$ decay.

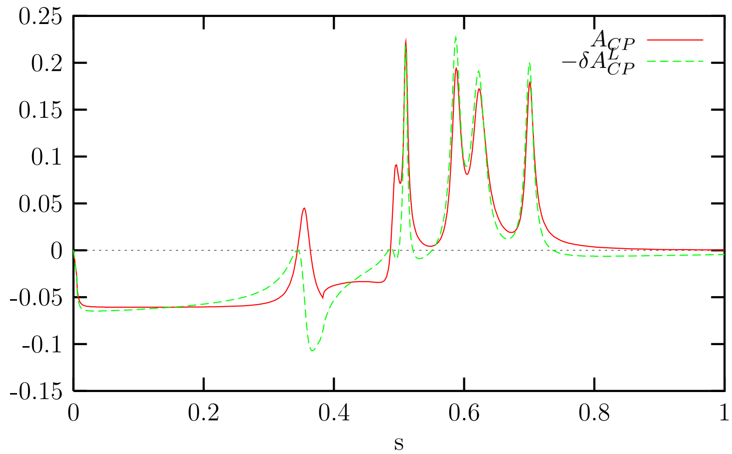

FIG. 3: Unpolarized CP violating asymmetry and longitudinally polarized quantity $-\delta A_{CP}^L$ for $B \to \pi e^+ e^-$ decay.

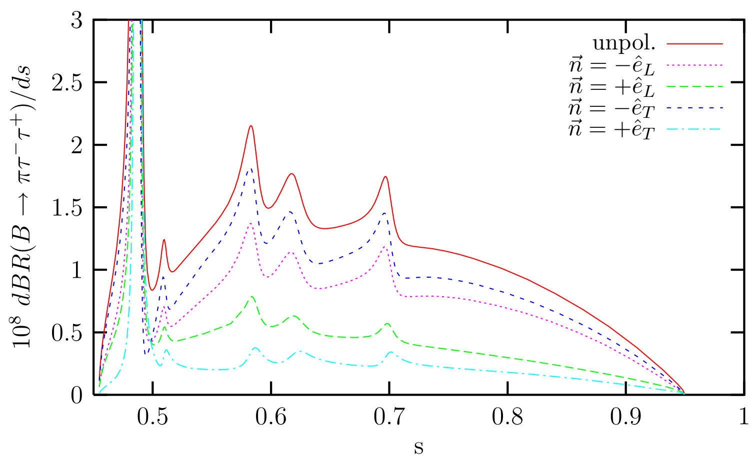

FIG. 4: Polarized and unpolarized differential branching ratios for $B \to \pi\tau^+\tau^-$ decay.

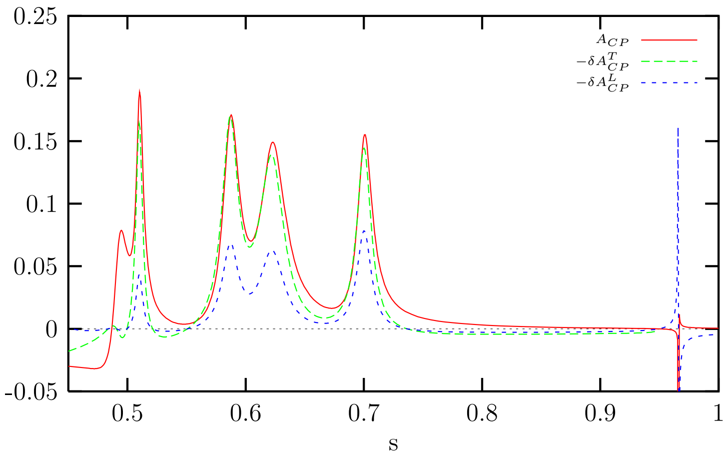

FIG. 5: Unpolarized A_{CP} and $-\delta A_{CP}^i$ with $i = L, T$ for $B \to \pi\tau^+\tau^-$ decay.

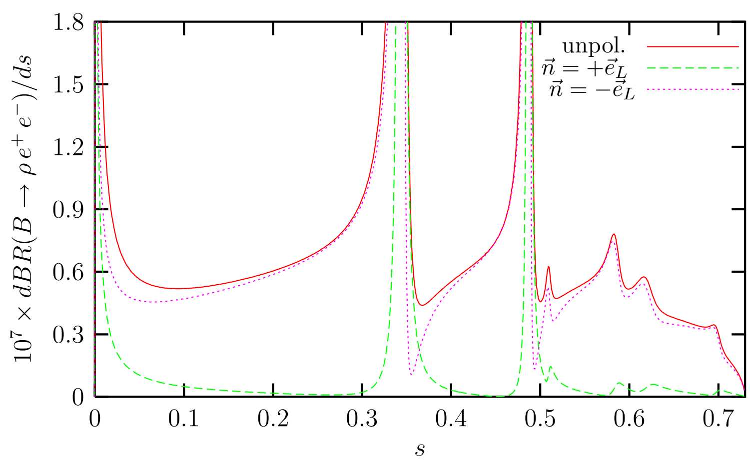

FIG. 6: Polarized and unpolarized differential branching ratios for $B \to \rho e^+ e^-$ decay.

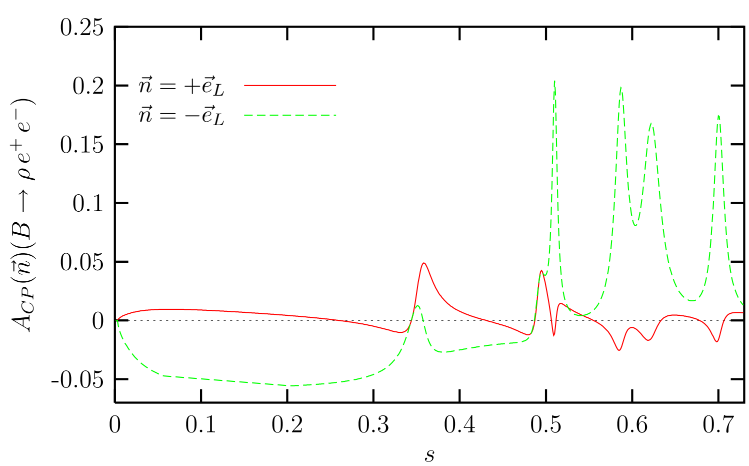

FIG. 7: Longitudinally polarized CP violating asymmetries for $B \to \rho e^+ e^-$ decay.

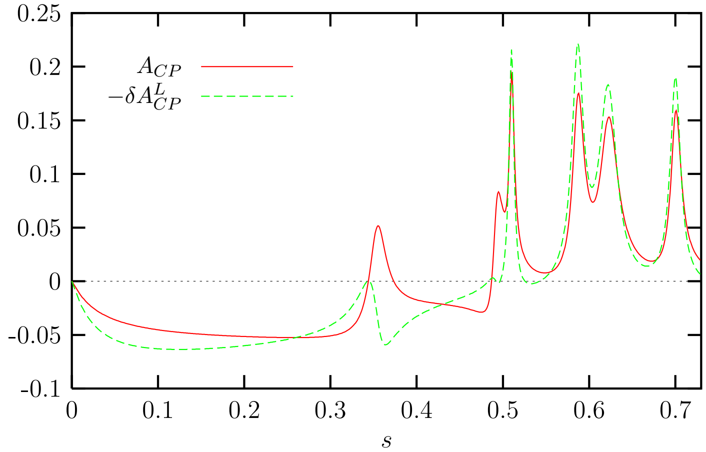

FIG. 8: Unpolarized CP violating asymmetry and longitudinally polarized quantity $-\delta A^L_{CP}$ for $B \to \rho e^+ e^-$ decay.

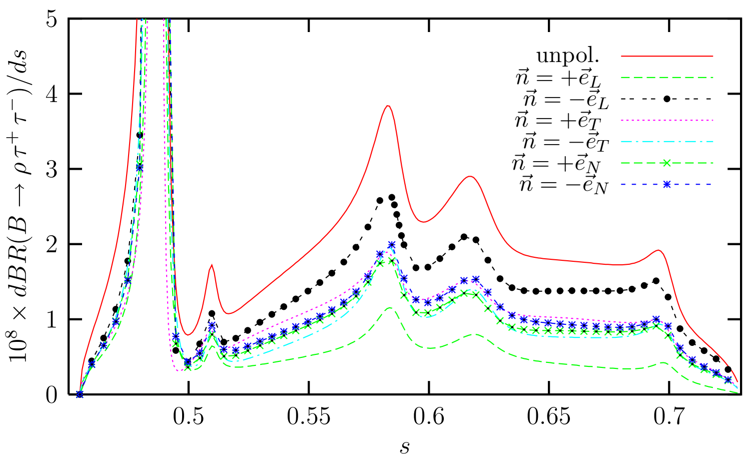

FIG. 9: Polarized and unpolarized differential branching ratios for $B \to \rho\tau^+\tau^-$ decay.

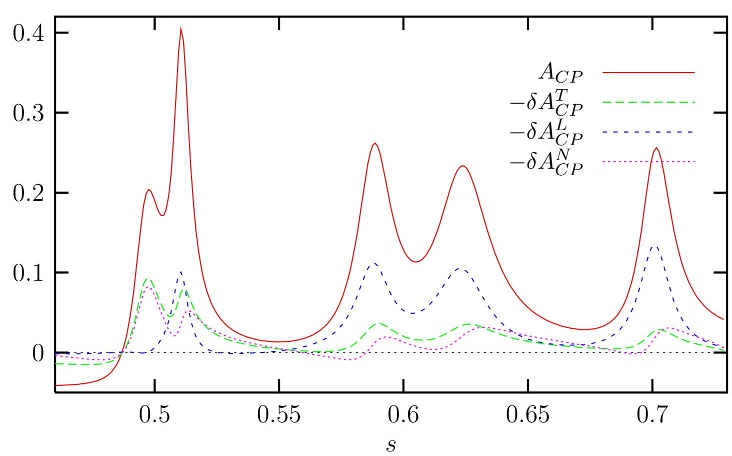

FIG. 10: Unpolarized A_{CP} and $-\delta A^i_{CP}$ with $i = L, T, N$ for $B \to \rho\tau^+\tau^-$ decay.